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ABSTRACT

A study examined whether conclusions about constructive processes in reading based on analysis of group data were consistent with those based on an analysis of individual data. Subjects, selected from a larger sample of 45 first grade students who had participated in a longitudinal study on acquisition of linguistic procedures for printed words, were from a variety of ethnic and cultural backgrounds and were relatively homogeneous in socioeconomic indicators. The same data set of reading-related processing measures was analyzed in four different ways. In the first approach, the analysis was based on achievement groups, aggregated over children drawn from different classrooms, with variation among children within the group treated as error. In the second approach, the analysis was based on instructional groups taught by the same teacher, with error estimated as in the first approach. Analysis in the third approach was based on the same children as the second approach but variation among children was treated as systematic variance and individual responses over stimulus trials were used to estimate error. Finally, in the fourth approach, separate analyses were performed for each child in the instructional groups in a design that used variation over stimulus trials to estimate error. Results depended on how the data were aggregated: the first two analyses indicated that there is one process in reading acquisition, while results of the last two analyses indicated that there is not one single process in learning to read. Rather, even when the instructional program was held constant, variation in children's constructive processes resulted in the learners using instructional cues in more than one way. Differences in conclusions were attributed to the ecological fallacy in which inferences about one unit of analysis are based on analyses at another level. (Five tables of data are included; 60 references are attached.) (Author/RS)

Ecological Fallacy in Reading Acquisition Research:[1,2,3,4] Masking Constructive Processes of the Learner

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[4]Based on a presentation at the 1990 meeting of the American Psychological Association.

Abstract

Different approaches to data analysis were applied to the same data set of reading-related processing measures in a first grade sample. In the first approach, the analysis was based on achievement groups, aggregated over children drawn from different classrooms. Variation among children within an achievement group was treated as error in this approach. In a second approach, the analysis was based on instructional groups taught by the same teacher. Again, variation among children within an instructional group was treated as error within this approach. In the third approach, analysis was based on the same children as in the second approach, but variation among children was treated as systematic variance and individual responses over stimulus trials were used to estimate error. In the fourth approach, separate analyses were performed for each child in the instructional groups in a design that used variation over stimulus trials to estimate error. Results from these four approaches depended on how the data were aggregated. Results of the first two analyses were consistent with previous literature that there is one process in reading acquisition, but children vary as to when they master the process. Results of the last two analyses suggest, in contrast, that there is not a single process in learning to read. Rather, even when the instructional program was held constant, variation in children's constructive processes results in the learners using instructional cues in more than one way. Differences in conclusions are attributed to the ecological fallacy in which inferences about one unit of analysis are based on analyses at another level. Conclusions about individuals should be based on statistical analysis of individuals, rather than on groups aggregated over individuals.

Ecological Fallacy in Reading Acquisition Research

Over a decade ago the paradigm shift from behaviorism to cognitivism was welcomed as a step "toward reinstating the learner, and his cognitive states and information processing strategies, as a primary determiner of learning" (Wittrock, 1974, p. 87). Since then the role of the learner as an active participant in the teaching-learning process has been increasingly emphasized (Weinstein & Mayer, 1986).

Input-output models, in which teaching directly influences achievement, are no longer thought to be plausible. Mediation models, in which teaching influences students' cognitive processes that in turn mediate learning and achievement, are thought to be more plausible (Wittrock, 1986). Mediation models distinguish among learner characteristics (what the learner knows), learning strategies (what the learner does during learning), encoding processes (how information is processed), and learning outcomes (what is learned) (Weinstein & Mayer, 1986).

The generative model (Wittrock, 1974, 1986; Languis & Wittrock, 1986) is an example of a mediation model. According to the generative model of reading comprehension, learners use previously acquired information processing strategies to construct adaptive responses to the reading stimulus. Learning--creating declarative or procedural representations--like remembering (Bartlett, 1932) is therefore a constructive process.

Constructive processes in other component reading skills such as word recognition have not been investigated. Rather, many researchers have emphasized how the same process underlies good and poor reading achievement. According to these researchers, the difference between good and poor readers is the rate at which readers master that process (e.g., Bruck, 1988; Fletcher, 1981; Stanovich, Nathan, & Zolman, 1988). Although some similarities among good and poor readers exist, we question whether there is one process involved at any level of reading acquisition because children's constructive learning processes may utilize instructional cues in varying ways. In a related vein, although the existence of multiple etiologies for reading disabilities is increasingly recognized (e.g., Doehring, Trites, Patel, & Fiedorowicz, 1981; Wolf, Bally & Morris, 1986), less consideration has been given to the possibility of multiple etiologies (i.e., processes) for normal reading acquisition.

These traditional approaches that search for one process underlying reading acquisition treat individual differences among children as error variance and do not provide a methodology for investigation of child-specific constructive processes. The major purpose of the research reported here was, therefore, to examine whether conclusions about constructive processes in reading based on analysis of group data are consistent with those based on analysis of individual data, especially in average and good readers (i.e., without reading disabilities). To accomplish this goal, the first step (Study

1) was to apply an approach that in previous research has supported the notion of one process in reading acquisition in which less abled readers, as compared to normal readers, follow the same process but just show a developmental lag. As in earlier studies of individual differences in reading acquisition (e.g., Juel, 1980; Perfetti & Hogaboam, 1975; Stanovich, 1980) we compared processing profiles of groups of excellent, average, and poor readers at the beginning, middle, and end of first grade. The processing profiles were based on the measures of linguistic task (lexical decision, naming, and written reproduction) and of word type (nonsense, phonically regular, and phonically irregular) described in Berninger (1988).

The second step (Study 2) involved an approach that has not been applied to studying whether or not there is one process in learning to read. We compared instructional groups of children instead of achievement groups to examine individual differences in processing profiles among children who were taught in the same instructional group in reading throughout first grade (teacher and instructional materials constant and achievement level comparable). In these analyses, instructional environment was kept as constant as is possible in the classroom outside the laboratory. If children in the same instructional group show differences on the measures of processing words, then evidence exists for individual differences in constructive processes in learning to read single words. Such evidence is consistent with the hypothesis that the learner's cognitive processes mediate the instruction received from teachers, thus supporting cognitive mediation models.

Three approaches to analysis were applied to the data from instructional groups. First, a group analysis was performed analogous to the previous analysis performed on the achievement groups. Variation among subjects was treated as error in a design that aggregated results over subjects. Second, a group analysis was performed in which subjects were treated as a separate variable in a design that aggregated results over stimulus trials. Third, a separate analysis using a design that aggregated results over stimulus trials was performed on each subject.

If different interpretations are supported by the contrasting approaches aggregating results over subjects or for a single subject, an ecological fallacy has occurred. The observation that results based on data aggregated over individuals and results based on individuals do not necessarily correspond (Burstein, 1980; Dogan & Rokkan, 1969; Peckham, Glass, & Hopkins, 1969; Robinson, 1950) has been called the ecological fallacy. In our first two analyses we examined data aggregated over subjects in groups to generate conclusions. In the last two analyses we analyzed data for an individual to generate conclusions about individuals. The ecological fallacy, which is related to the unit of analysis, has been considered in the sociological literature where it was first elaborated (e.g., Robinson, 1950) and in educational research on organizational climate (e.g, Sirotnik, 1980) and aptitude-treatment interactions (e.g., Burstein, 1980; Cronbach, 1976), but not in reading research. We reasoned that investigations of individual differences in reading acquisition in general (i.e., whether there is one process or more than one process), and of constructive processes in particular, need to analyze data for individuals in order to avoid the potential ecological fallacy of making inappropriate statements about individuals' reading processes based on the analysis of data aggregated by groups.

Study 1

Subjects

Overall sample. Children for Study 1 and for Study 2 were selected from a larger sample of 45 first grade students who had participated in a year-long longitudinal study described in Berninger (1988). All these children had passed a kindergarten screening for severe developmental, learning, language, or emotional disorders. Their Verbal IQs, as measured by the Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981) and the Vocabulary Subtest of the Wechsler Intelligence Scale for Children-Revised (Wechsler, 1974), ranged from low average to very superior. This middle-class sample was relatively homogeneous in socioeconomic indicators, but included children from a variety of ethnic and cultural backgrounds. Any child who had repeated first grade was excluded from participation. The schools, which had a reputation for high academic achievement, did not introduce formal reading instruction until the beginning of first grade. The teachers used a variety of instructional methods in the reading program: directed reading activities with basal readers, explicit instruction in phonics rules, and language experience stories for science and social studies. Each classroom teacher organized the reading program around three to five small reading groups, with an average of four or five students.

Top, middle, and lowest achievement groups in the total sample. Three subgroups of nine children each were identified in the larger sample of 45 children based on the observed distribution of oral and silent reading achievement scores at the end of first grade. The top group (5 girls, 4 boys) of best readers included those who had at least a 4.1 grade equivalent on the Slosson Oral Reading test (Slosson, 1963) and at least a 2.8 grade equivalent on the Gates MacGinitie Vocabulary Test (MacGinitie, 1978). The middle group (5 girls, 4 boys) of the most-average readers included those who scored between a 2.2 and 2.9 grade equivalent on the Slosson Test and between a 2.1 and 2.8 grade equivalent on the Gates MacGinitie. The lowest group (6 girls, 3 boys) of the worst readers included those at or below a 1.6 grade equivalent on the Slosson Test and at or below a 1.7 grade equivalent on the Gates MacGinitie. These children were drawn from different classrooms and reading groups and thus did not experience a common instructional environment.

Procedures

Equipment and general testing considerations. Measures for the processing profile were obtained from an experiment administered repeatedly in individual sessions of approximately one hour in the second month, fifth month, and eighth month of first grade. The investigator was seated at a portable microcomputer, which regulated randomized stimulus presentation. The child was seated in front of a 12-inch monitor and touch-sensitive keyboard and voice-activated relay, all of which were configured with the microcomputer. Responses were excluded from analysis when attention waned or there was a distraction or interruption. Children were rewarded for responding whether the response was correct or not. A smiley face or one of three personalized messages with the child's name followed each response trial. At the completion of the study each child was given a book.

Three linguistic tasks. Children were randomly assigned to order of linguistic task, each of which occurred about the same number of times at the beginning, middle, and end of the session. For the lexical decision task, children were instructed to press the *yes* label if the word was a real word that means something, but to press the *no* label if the word is not a real word, just a made-up word that does not mean anything. Lexical decisions could not be made solely on the basis of phonological recoding because the stimulus might be pronounceable, but not a real word with meaning, as in the case of nonsense words; thus, lexical decision probably included both prelexical and postlexical processes and some semantic processing (see Chumbley & Balota, 1984).

For the naming task, the children were instructed to say the word aloud and to read it clearly in a normal speaking voice into the microphone (voice activated relay). Naming required production of a phonetic (name) code--segmental phones and suprasegmental intonation--and not just a phoneme string; a sequence of sounds without normal accent patterns and intonational contour was counted as an error.

For the written reproduction task, the children were instructed to look carefully at the word flashed on the monitor, and after it disappeared, to write exactly what they had seen--as much of the word as they could remember. They were given primary pencils and lined paper to write the words. Written reproduction required the child to look carefully at the displayed word, remember it after the display disappeared, and construct the grapho-motor plans to reproduce the word by writing it.

These three linguistic tasks were chosen because access to semantic codes was obligatory (lexical decision), access to name codes was obligatory (naming), or access to orthographic codes was obligatory (written reproduction). For each task non-obligatory codes may also be activated and probably were (Berninger, 1988).

Nature of Stimulus Information

Three types of three-letter stimulus words were used. Length of word was kept constant because it can influence lexical decision and naming (Chumbley & Balota, 1984). The three kinds of stimulus words differed in the kind of information potentially available for linguistically coding (Berninger, in press). Phonically regular real words can be coded phonologically (phonemically), phonetically, semantically, and orthographically, and can be decoded by application of a phonics rule of letter-phoneme correspondence to every letter in a word (e.g., "cat"). Phonically irregular real words can be coded phonetically, semantically, and orthographically, but cannot be decoded by applying a phonics rule to every letter in the word because of either silent letters (e.g., "t<u>w</u>o") or violations of usual phonics rules (e.g., "w<u>as</u>"). We did not call these exception words because although not every letter could be phonologically (phonemically) coded, the first letter could be; and they were orthographically legal and often orthographically, if not phonologically, regular (Berninger, in press; Berninger, 1989). Nonsense words can be coded phonologically (phonemically) and orthographically; they can be decoded by applying a phonics rule to every letter in the word (e.g., "pom") or by analogy (spelling pattern in known word) to construct a phonetic code.

The phonically regular words (Gibson, Osser, & Pick, 1963) and phonically irregular words (Dolch, 1960) were selected from word lists used in previous research with first graders in order to ensure that they would be frequent words familiar to beginning readers. Four different stimulus words for each of the three different kinds of words (phonically regular real words, phonically irregular real words, and nonsense words) were replicated three times each within the three blocked conditions for linguistic tasks.

Data Analysis

Only frequency of consistently correct responses over three replications of the same stimulus word was analyzed for each of the three tasks. Because lexical decision involved response selection (yes/no binary choices), but naming and written reproduction require response production, the probability of correct responding based on chance alone is higher for lexical decision than for the other tasks. If, however, a correct response is produced to the same stimulus word on three randomized trials, it was judged unlikely that the child is responding randomly on the binary choice task. Altogether, there were eight replicated stimulus trials for each combination of level of a linguistic task and a level of stimulus information.

In the analysis based on achievement groups, a 3 x 3 x 3 x 3 analysis of variance was performed in which achievement group (top, middle, and low) was a between-subjects variable. Time (beginning, middle, and end first grade), task (lexical decision, naming, and written reproduction), and word type (nonsense words, phonically regular words, and phonically irregular words) were within-subjects variables. We were specifically interested in interactions involving the achievement group variable. Previous research (Berninger, 1988) in which achievement group was not considered in the analysis had shown (a) significant effects for task (lexical decision > naming > written reproduction) at the beginning, middle, and end of first grade, although the gap between naming and written reproduction had virtually been eliminated by the end of first grade; and (b) significant effects for word type on lexical decision at the beginning, middle, and end of first grade (phonically regular words > letter strings > phonically irregular words > nonsense words); on naming at the beginning, middle, and end of first grade (phonically regular or irregular real words > nonsense words); and on written reproduction at the beginning, middle, and end of the year (phonically regular words > phonically irregular words > nonsense words > letter strings).

Results

A summary of the results of the analysis of variance is reported in Table 1. The dependent measure was a summary score ranging from 0.0 to 8.0. There was a significant main effect for achievement group--top group, $\underline{M}$ = 5.94, middle group, $\underline{M}$ = 4.07, and low group, $\underline{M}$ = 2.54--and for time--beginning of first grade, $\underline{M}$ = 2.48, middle of first grade, $\underline{M}$ = 4.25, and end of first grade, $\underline{M}$ = 5.84. There was also a significant main effect for task--lexical decision, $\underline{M}$ = 4.83, naming, $\underline{M}$ = 3.93, and written reproduction, $\underline{M}$ = 3.79--and for word type--phonically regular words, M = 5.02, phonically irregular words, M = 4.49, and nonsense words, M = 3.05.

There was a significant interaction between task and time: lexical decision, M = 3.52, and naming, M = 2.30, at the beginning of the year, but lexical decision, M = 5.98, and naming, M = 5.57, at the end of the year. There was a significant interaction between word type and time: mean gain of 4.04 for phonically regular words compared to a mean gain of 2.58 for nonsense words from the beginning to the end of first grade. There was a significant interaction between word type and task: phonically regular words, M = 5.84, and phonically irregular words, M = 4.62, on lexical decision; phonically regular words, M = 4.44, and phonically irregular words, M = 4.03, on written reproduction; and phonically irregular words, M = 4.82, and phonically regular words, M = 4.77, on naming. The three-way interaction was related to phonically irregular words > phonically regular words on naming at the middle of the year, while the rank order was phonically regular words > phonically irregular words > nonsense words on all tasks at the other times of the year and on the other tasks in the middle of the year.

Insert Table 1 about here

Of most interest were the significant interactions involving achievement groups: achievement group X time, achievement group X task, and achievement group X time X word type. The low group at the end of the year (M = 4.35) was comparable to the middle group at the middle of the year (M = 4.12). The middle group at the end of the year (M = 6.25) was comparable to the top group at the middle of the year (M = 6.09). The top group was equally good on lexical decision (M = 6.20) and naming (M = 6.19), but the middle group and low group were better on lexical decision (M = 4.74, middle group; M = 3.54, low group) than on naming (M = 3.75, middle group; M = 1.86, low group). In the top and low groups, phonically regular words were consistently superior to phonically irregular words, which were consistently superior to nonsense words throughout the year. In the middle group, this pattern was found at the middle and end of first grade only; at the beginning of first grade phonically irregular words were superior to phonically regular words, which were superior to nonsense words.

Results for each combination of linguistic task and word type are reported in Table 2 for the low group at the end of year and the middle group at middle of the year and for the middle group at the end of the year and the top group at the middle of the year to illustrate the group x time interaction. Comparison of these process variables at times the overall performance was comparable indicates that they are remarkably similar.

Insert Table 2 about here

Discussion

The results in this analysis, based on a comparison of achievement groups, aggregated over individuals within a first grade sample, support the notion of a single process in reading acquisition as does the work by Stanovich et al. (1988). The low group differs from the average group and the average group differs from the top group in rate of reading acquisition rather than in the process. Indeed, when skill levels of groups are comparable, the process appears to be essentially the same. The theoretical significance of the reading-related process variables is discussed in Berninger (1988) and will not be considered in this paper, which is primarily concerned with the methodological issue of the unit of analysis.

Study 2

Subjects

Top, middle, and lowest instructional group of the same teacher. Intact reading groups had been formed by participating teachers at the beginning of the year on the basis of readiness scores, kindergarten teachers' recommendations, and first-grade teachers' observations of daily performance. For purposes of this study, the teacher was selected whose top, middle, and lowest groups (a) contained the most children participating in this study, (b) showed the best distribution of numbers of children across the three levels of instruction, and (c) did not change in composition across the year. The top group (n = 4) consisted of 3 boys and 1 girl whose grade equivalents ranged from

.6 - 1.0 on the Slosson Test at the beginning of first grade and from 2.9 to 3.8 on the Slosson Test at the end of first grade. The middle group (n = 4) consisted of two boys and two girls whose grade equivalents ranged from .1 to .4 on the Slosson Test at the beginning of first grade and 1.9 to 2.7 on the Slosson Test at the end of first grade. The low group (n = 4) consisted of two boys and two girls whose grade equivalents ranged from 0 to .1 on the Slosson Test at the beginning of first grade and from 1.2 to 2.0 on the Slosson Test at the end of first grade.

Within an instructional group each child was exposed to the same instruction, instructional materials, and seatwork assignments. In different reading groups the same teacher taught different lessons, used different instructional materials, and assigned different independent work to students. Even though the teacher was constant, the instructional program could vary across instructional groups within the same classroom. The purpose of these analyses was to investigate individual differences among the four children who belonged to the same instructional group within that class and therefore shared the same instructional program within the larger classroom.

Procedures of Data Collection

These were identical to those described for Study 1.

Data Analyses

First, analysis of variance was performed on summary scores (across 8 items) over subjects in a 3 x 3 x 3 x 3 design analogous to the analysis for the achievement groups. Instructional groups were a between-subject variable and time, task, and word type were within-subject variables. Variation among children within the same instructional group was treated as error. A second analysis of variance was performed on individual items over stimulus trials in a 12 x 3 x 3 x 3 design. Subjects were treated as a separate, explanatory variable in this design. The third analysis was a series of single-subject analyses of variance performed for each of the 12 subjects in the three instructional groups taught by the same teacher. In the second and third analyses a _1_ was entered for a consistently correct response across three replications of a stimulus, a _0_ was entered for incorrect responses or inconsistently correct responses. Stimuli were treated as independent measures across word type and linguistic task because stimulus trials were randomized across subjects and not paired across conditions at a given time. The second analysis (group design) and third analysis (individual subject design) were analogous in that the designs aggregated responses over individual stimulus items.

Results

The results of the first analysis of variance that treated variations among subjects in the same instructional groups as error are reported in Table 3. These results for instructional groups are remarkably similar to those for the achievement groups reported in Table 1. The only differences are (a) the interaction between group and task, which just reached conventional levels of significance for the achievement group (see Table 1), but missed conventional levels of significance for the instructional groups (see Table 3); and (b) the interaction between time and task and word type, which just reached conventional levels of significance for the achievement groups (see Table 1) but missed conventional levels of significance for the instructional groups (see Table 3). In general, results based on a smaller sample (N = 12) are comparable to those based on a larger sample (N = 27).

The results of the analysis of variance that tested for effects due to individual differences among children/are reported in Table 4. Clearly, trends depend on individuals. Also, the form of the interaction depends upon the individuals. All 2-way and 3-way interactions (but not the 4-way interaction) involving individuals were statistically significant; see Table 4. These results justify follow-up analysis of individuals. Although we could have orthogonally decomposed the effects in Table 4, we chose to do an analysis of variance for each child so that we could illustrate the various patterns of results by child. Because the individual differences may simply be related to differences among achievement levels, we were especially interested in potential individual differences within the same instructional group.

Insert Tables 3 and 4 about here

The results for the second analysis of variance or instructional groups treating subjects as error (Table 3) and the analysis of instructional groups treating subjects as an explanatory variable (Table 4) are remarkably similar. The only differences are (a) the time x task x word type interaction just missed conventional levels of significance when subjects were treated as the error term (Table 3) but just reached conventional levels of significance when individuals were treated as a separate variable (Table 4); and (b) the significance of the individual differences variable and its interaction with all the other variables became apparent <u>only</u> when it was analyzed as an explanatory variable.

As shown in Table 5, all children showed a main effect for time and were more accurate at the end than at the middle or at the beginning of first grade. Otherwise, there were considerable individual differences among subjects within the top group, within the middle group and within the low group as to which effects and interactions in the individual analyses were statistically significant. Even when more than one child within the same instructional group showed a main effect for a particular variable or a significant interaction between specific variables, the pattern of the levels of variable or of the interaction were often not the same.

Top instructional group. Within this group, all subjects showed a main effect for word type. Only one subject (S3)showed a main effect for task. Three of the top group showed significant interactions: S2 (word type X task; and time X task), S3 (time x task), and S4 (word type x time; word type x task; and time x task).

Insert Table 5 about here

Middle instructional group. Within this group, three subjects (S5, S6, S7) showed effects due to word type. Three subjects (S5, S7, S8) showed effects due to task. Three (S6, S7, S8) showed significant interactions: S6 (word type x task); S7 (word type x task; time x task); and S8 (word type X task; word type X time).

Low instructional group. Within this group, all four showed significant word type effects. Two (S9, S11) showed a main effect for task. All showed significant interactions: S9 (word type x time; word type x task; time x task); S10 (time x task); S11 (word type x time); and S12 (word type x time).

Discussion

These analyses of individual subjects revealed variation in main effects for word types and linguistic tasks and in two-way interactions among the three variables (time, word type, and linguistic task) within a given instructional group. Some children varied by not showing the significant main effects or interactions that occurred in the group analysis (see Tables 4 and 5), while others differed in the individual analyses compared to their peers in the same instructional group. This variation cannot be accounted for by differences in instructional program or material, and is more likely attributable to the constructive processes of learners. This variation is constrained, however, with certain patterns reoccurring. However, none of the children in the same instructional group showed exactly the same processing profile (in terms of significant main effects and interactions).

General Discussion

Cronbach (1957) called attention to the two contrasting approaches that psychologists use for dealing with variability among subjects. One approach is to focus on group averages and disregard variation among subjects in order to draw conclusions about the general human mind. The other approach is to focus on the individual subject and disregard commonalities across subjects in order to draw conclusions about individual differences. While experimental psychology has tended to emphasize group differences (treatment effects that exceed individual differences among people), clinical psychology (differential psychology) has tended to emphasize individual differences (performance on tests that were constructed to measure differences among people), although, of course, exceptions do exist.

Wittrock (1974, p. 73) has argued that the generative model is one way that educational psychology can "conceptualize important problems that cut across differential and experimental psychology." The generative model acknowledges that learning is a function of memory representations generated from prior experience and the stimuli to be processed. Although the experimenter can manipulate the stimuli to be processed and the task requirements, the experimenter can never fully control memory representations generated from prior experience. Rather than treating those individual differences resulting from learner characteristics or prior experience as error variance in analysis of variance, the experimenter operating within a generative theoretical framework studies those individual differences for clues to the constructive processes of the learner that mediate stimulus input. "Even if all learners were to have identical backgrounds, which is, of course, not conceivable, the relation between their experiences and the instruction would still be crucially important" (Wittrock, 1974, p. 93).

Although constructive processes in reading comprehension have been investigated previously (Wittrock, Marks, & Doctorow, 1975), the research reported here is the first to highlight the constructive process in learning to decode and encode single printed words. The theoretical significance of effects of linguistic task and nature of stimulus information and of interactions between these variables for learning to decode and encode single printed words is dealt with elsewhere (Berninger, 1988. in press). The main goal here was to document that constructive processes exist within learners for these variables in decoding and encoding single printed words and to argue that we must use designs that allow us to test for individual differences in such constructive processes.

A sizable amount of research literature exists on aptitude-treatment interactions (ATI), that is, adapting instruction to individual differences in aptitude, broadly defined to include intellectual abilities, prior knowledge, motivational/personality variables) and cognitive or learning styles (Corno & Snow, 1986). Many teacher behaviors, however, demonstrate a nonlinear relationship with student achievement (Good & Brophy, 1986). Because the teacher's instructional input and the student's learning processes may not be directly related (Gibson & Levin, 1975), the question this research raised of whether individual differences in the learning process may exist when instructional input is held constant is of theoretical importance.

Aptitudes, resulting from individual differences in inherited abilities and in life experiences, may constrain how mental procedures for information processing (Kolers & Roediger, 1984) are constructed, much as the processing capabilities of a computer's operating system constrain how programs can be created. Yet, aptitudes are not identical with the processes of constructing or instantiating mental procedures. Likewise, a computer's processing capabilities and operations are not identical. In contrast to ATI research, which has focused on interactions between pre-instruction aptitude and instruction, the present research investigated whether mental procedures or processing operations that are constructed during the learning process are variable or uniform across learners when "instruction" is held constant.

One implication of this research approach for reading researchers is that investigations should not be confined to individual differences in aptitude and how these interact with instruction but rather should also explore individual differences in the constructive processes of the learner when instruction is held constant. Another implication of this research is that because of these constructive processes there is more than one way to learn to read, for superior, average, and poor readers. Instead of seeking one process in learning to read we should seek a single, unified model of the various processes involved in learning to read, any one of which might break down in an individual child or which might be utilized in a variant fashion by an individual child.

The contribution of the research reported here is not, therefore, to demonstrate yet again that individual differences exist in reading--for example, in lexical access (Coltheart, 1978), in reliance on letter-sound correspondences or word-specific associations (Baron, 1979; Baron & Strawson, 1976; Treiman, 1984), in skilled reading components (Fredericksen, 1980), or in saccade and fixation duration (Rayner, 1984). Rather, the significance of this research lies in applying both group and individual subject analyses in order to demonstrate (a) variability among learners within the same instructional group when the instructional program is held as constant as possible within a classroom and (b) variability within the same learner from the beginning to the middle to the end of first grade.

Group analyses show that reading-related information processing differs as a function of achievement level, but is similar at comparable stages of the learning process. Group analyses, however, may mask constructive processes of individual subjects. Insignificant differences between older, less-skilled readers and younger, more-skilled readers (e.g., Stanovich et al., 1988) or between top and average readers or average and low readers at certain times during first grade (this study) provide indirect evidence for the notion of one process in reading acquisition with different rates of mastering that process. We can fail to refute the null hypothesis, but we cannot prove it. Individual analyses, on the other hand, reveal varying constructive processes within top, average, and low beginning readers. Differences between results of group and individual analyses cannot be attributed to ceiling or floor effects, neither of which was found on the experimental variables (Berninger, 1988).

The unexamined presupposition of much scientific inquiry has been that an either/or answer exists that can be discovered through hypothesis testing. Variability is considered a nuisance that well designed experiments will minimize (Kantowitz & Roediger, 1978). A more appropriate presupposition in the case of learning is that the process itself is variable and open to modification and refinement. For example, learning processes may vary (a) <u>within the same subject over a short time period</u>, as a consequence of random variation in signal detection (Swets, 1964), or of systematic variation in the on-line processing (Rayner, 1984); (b) <u>within the same subject over a long time period</u>, as a consequence of normal variation in neural maturation (Wolff, 1981), or (c) <u>among subjects at a given point in time</u>, as a consequence of interactions between inherited processing capabilities and qualitatively different procedural operations constructed by the learner for processing instructional information (Berninger, 1986). The design of the present experiment permitted investigation of variation in processes related to reading both within the same subject over three-month intervals and among subjects at the same time.

On the one hand, we can assume individual differences are error variance and look for group effects based on aggregations of individuals to draw inferences about the commonalities in nature. On the other hand, we can focus on person effects based on aggregations of stimulus trials to draw inferences about normal variation among individuals. By focusing on either approach, to the exclusion of the other, we may overlook important and interesting aspects of the learning process. Indeed, both relative uniformity and normal variation may be a fundamental characteristic of the human information processing system. The uniformity results because genetic inheritance is similar, if not identical (Minsky, 1986), and instructional experiences are similar, if not identical. The variability results because human learners are not programmed externally as computers are; thus human learners may vary in how they use external cues to construct their own mental programs even when an instructional environment is held constant.

(16)VB-R

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Table 1

Summary Analysis of Variance Table for Groups Defined by Achievement and Drawn from Different Classrooms (N = 27)

Source	S.S.	df.	M.S.	F
Achievement Group	1,415.28	2	707.64	67.8**
Subjects (Achievement Group)	250.64	24	10.44	
Time	1,395.20	2	697.60	184.8**
Achievement Group X Time	109.08	4	27.27	7.2**
Subjects (Achievement Group) X Time	181.21	48	3.78	
Task	154.18	2	77.09	22.9**
Achievement Group X Task	58.69	4	14.67	4.4**
Subjects (Achievement Group) X Task	161.73	48	3.37	
Time X Task	81.54	4	20.38	10.9**
Achievement Group X Time X Task	19.67	8	2.46	1.3
Subjects (Achievement Group) X Time X Task	178.86	96	1.86	
Word Type	505.60	2	252.80	54.7**
Achievement Group X Word Type	28.72	4	7.18	1.6
Subjects (Achievement Group) X Word Type	221.83	48	4.62	

Table 1 (Continued)

Source	S.S.	df.	M.S.	F
Time X Word Type	61.82	4	15.45	9.7**
Achievement Group X Time X Word Type	73.05	8	9.13	5.7**
Subjects (Achievement Group) X Time X Word Type	152.99	96	1.59	
Task X Word Type	94.24	4	23.56	10.5**
Achievement Group X Task X Word Type	35.66	8	4.46	2.0[a]
Subjects (Achievement Group) X Task X Word Type	216.17	96	2.25	
Time X Task X Word Type	21.95	8	2.74	2.1*
Achievement Group X Time X Task X Word Type	29.41	16	1.84	1.4
Subjects (Achievement Group) X Time x Task X Word Type	247.23	192	1.29	

* $p < .05$

** $p \leq .01$

[a] $p < .06$

Table 2

Comparison of Combinations of Task and Word Type for Reading Skill Groups (Drawn from Different Classrooms) at Times Their Overall Performance was Comparable

	Lexical Decision			Naming			Written Reproduction		
	NW[a]	PR[b]	PI[c]	NW	PR	PI	NW	PR	PI
Middle Group Middle of Year (n = 9)	3.0[d]	6.6	4.7	0.4	4.9	6.3	2.0	5.2	4.0
Low Group End Year (n = 9)	3.7	6.3	4.2	1.0	5.1	5.4	2.9	5.4	5.0
Top Group Middle Year (n = 9)	5.0	7.6	6.3	4.8	7.1	6.8	4.8	6.3	6.1
Middle Group End Year (n = 9)	5.3	8.0	5.6	3.4	7.1	6.8	5.8	7.2	7.0

[a] Nonsense words

[b] Phonicaly regular words

[c] Phonically irregular words

[d] These entries are cell means across subjects. Possible range is from 0.0 to 8.0.

Table 3

Summary Analysis of Variance Table for Instructional Groups Taught by the Same Teacher in the Same Classroom (N=12)

Source	S.S.	df.	M.S.	F
Instructional Group	275.63	2	137.82	27.8**
Subjects (Instructional Group)	44.67	9	4.96	
Time	1,010.02	2	505.01	325.9**
Instructional Group X Time	28.91	4	7.227	4.7**
Subjects (Instructional Group) X Time	27.89	18	1.55	
Task	48.91	2	24.45	12.9**
Instructional Group X Task	19.69	4	4.92	2.6[a]
Subjects (Instructional Group) X Task	34.00	18	1.89	
Time X Task	78.57	4	19.64	10.6**
Instructional Group X Time X Task	25.44	8	3.18	1.7
Subjects (Instructional Group) X Time X Task	66.94	36	1.86	
Word Type	255.06	2	127.53	34.5**
Instructional Group X Word Type	14.54	4	3.63	1.0
Subjects (Instructional Group) X Word Type	66.56	18	3.70	

Table 3 (Continued)

Source	S.S.	df.	M.S.	F
Time X Word Type	28.70	4	7.18	3.6*
Instructional Group X Time X Word Type	40.81	8	5.10	2.5*
Subjects (Instructional Group) X Time X Word Type	72.56	36	2.02	
Task X Word Type	65.98	4	16.50	8.6**
Instructional Group X Task X Word Type	12.87	8	1.61	0.8
Subjects (Instructional Group) X Task X Word Type	68.78	36	1.91	
Time X Task X Word Type	18.26	8	2.28	1.9[b]
Instructional Group X Time X Task X Word Type	17.61	16	1.10	0.9
Subjects (Instructional Group) X Time X Task X Word Type	87.61	72	1.22	

* $p < .05$

** $p \leq .01$

[a] $p < .07$

[b] $p < .08$

Table 4

Summary Analysis of Variance Table for Instructional Groups Taught by the Same Teacher in the Same Classroom (N = 12) with Individuals as Separate, Explanatory Variable

Source	S.S.	df.	M.S.	F
Main Effects				
Individuals	39.91	11	3.63	23.91**
Word Type	32.19	2	16.10	106.08**
Time	126.80	2	63.40	417.84**
Task	5.99	2	2.99	19.72**
2-way Interactions				
Individual X Word Type	10.38	22	0.47	3.11**
Individual X Time	7.05	22	0.32	2.11**
Individual X Task	6.78	22	0.31	2.03**
Word Type X Time	3.45	4	0.86	5.69**
Word Type X Task	8.16	4	2.04	13.45**
Time X Task	9.64	4	2.41	15.89**

Table 4 (Continued)

Source	S.S.	df.	M.S.	F
3-way Interactions				
Individual X Word Type X Time	14.20	44	0.32	2.13**
Individual X Word Type X Task	10.57	44	0.24	1.58**
Individual X Time X Task	11.39	44	0.26	1.71**
Word Type X Time X Task	2.33	8	0.29	1.92*
4-way Interaction				
Individual X Word Type X Time X Task	12.97	88	0.15	0.97
Residual	344.13	2268	0.15	

* $p \leq .05$

** $p \leq .01$

Table 5

Summary Table of Significant Effects in Individual Analyses of Variance within Three Instructional Groups Taught by the Same Teacher in the Same Classroom

Subject	Source	S.S.	df.	M.S.	*F*
Top Group					
S1	Word Type	2.07	2	1.03	5.94*
	Time	11.73	2	5.87	33.72**
S2	Word Type	8.79	2	4.39	29.79**
	Time	10.68	2	5.34	36.19**
	Word Type X Task	1.63	4	.41	2.76*
	Time X Task	2.41	4	.60	4.08**
S3	Word Type	1.68	2	.84	5.63**
	Time	7.37	2	3.69	24.76**
	Task	2.01	2	1.01	6.75**
	Time X Task	3.63	4	.91	6.10**

Table 5 Continued

Subject	Source	S.S.	df.	M.S.	_F_
S4	Word Type	3.82	2	1.91	13.35**
	Time	11.57	2	¯.78	40.48**
	Word Type X Time	2.41	4	.60	4.21*
	Word Type X Task	1.52	4	.38	2.66*
	Time X Task	2.94	4	.73	5.14**
Middle Group					
S5	Word Type	6.78	2	3.39	21.71**
	Time	10.75	2	5.38	34.44**
	Task	2.03	2	1.01	6.50**
S6	Word Type	2.70	2	1.35	7.46**
	Time	10.84	2	5.42	29.92**
	Word Type X Task	2.35	4	.59	3.25**

Table 5 (Continued)

Subject	Source	S.S.	df.	M.S.	F
S7	Word Type	5.62	2	2.81	18.64**
	Time	7.26	2	3.63	24.07**
	Task	2.62	2	1.31	8.69**
	Word Type X Task	2.30	4	.57	3.81**
	Time X Task	1.99	4	.50	3.30**
S8	Time	14.37	2	7.19	45.27**
	Task	.95	2	.48	3.00*
	Word Type X Time	1.52	4	.38	2.39*
	Word Type X Task	3.85	4	.96	6.07**

Table 5 (Continued)

Subject	Source	S.S.	df.	M.S.	F
Low Group					
S9	Word Type	.86	2	.43	3.43*
	Time	15.53	2	7.76	61.78**
	Task	1.08	2	.54	4.31**
	Word Type X Time	3.36	4	.84	6.69**
	Word Type X Task	2.31	4	.58	4.59**
	Time X Task	2.72	4	.68	5.42**
S10	Word Type	2.29	2	1.14	6.81**
	Time	11.79	2	5.89	35.08**
	Time X Task	1.85	4	.46	2.76**

Table 5 (Continued)

Subject	Source	S.S.	df.	M.S.	*F*
S11	Word Type	5.33	2	2.67	21.33**
	Time	11.19	2	5.60	44.78**
	Task	1.86	2	.93	7.44**
	Word Type X Time	2.14	4	.54	4.28*
S12	Word Type	1.75	2	.88	6.15**
	Time	10.78	2	5.39	37.90**
	Word Type X Time	1.97	4	.49	3.47**

* $p \leq .05$, ** $p \leq .01$